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Effect of Bagging on Moisture Change in Cotton Bales

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Abstract. The purpose of this research was to determine the moisture transfer and weight gain of universal density cotton bales packaged in different materials. Bagging materials investigated included both woven polypropylene bags with extrusion-coated strips to prevent fibrillation as well as similar bags that were fully coated on the interior to reduce contamination. Three bales each were ginned, packaged, and placed in four different types of bags—two types of woven polypropylene spiral sewn bags with alternating extrusion-coated and uncoated strips, and two types of fully coated bags. Initial moisture contents averaged 3.6%. The bales were stored for 140 days at 70% relative humidity (RH) and then at 50% RH for 88 additional days. Bales were weighed and measured for thickness twice each week. After 140 days, the strip-coated bales averaged 6.9% moisture and the fully coated bags averaged 5.3%. After an additional 88 days of storage at 50% RH, the strip-coated bales averaged 5.9% moisture and the fully coated bags still averaged 5.3%. The bales in the fully coated woven polypropylene bagging changed moisture much more slowly than those in the strip-coated materials. Bale thickness changed from as little as 0.3 cm (0.1 in.) to as much as 2.2 cm (0.8 in.) as moisture content changed for the bales in the four types of bagging. Fiber quality did not change during storage.

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Introduction

The physical condition of cotton bales produced in the United States has improved remarkably since formation of the Joint Cotton Industry Bale Packaging Committee (JCIBPC) in 1968. The switch to net weight trading dramatically reduced the weight of the packaging materials that were mostly jute and flat steel bands in 1968. Currently, most bales are packaged in woven polypropylene or polyethylene film and restrained with wire ties. Tare weights for bagging and ties have decreased from 9.5 kg (21 lbs) to 2.3 kg (5 lbs) since 1968. As bale storage or handling practices change and new technology emerges, new types of bagging and ties are developed in response to the new requirements. The JCIBPC thoroughly investigates new bagging or tie materials to ensure that they perform satisfactorily before approving widespread commercial use. Some of the early evaluation of the new materials is done at the U.S. Cotton Ginning Laboratory at Stoneville, MS. The Stoneville studies usually involve accelerated conditioning at high or low humidity in order to quickly assess the response of the new materials prior to commercial testing.

After the cotton fiber is packaged into a bale, moisture transfer occurs very slowly especially at high densities. In fact, bales at densities of 192 kg/m^3 (12 lb/ft^3) required over 60 days to equilibrate with the environment while bales at 448 kg/m^3 (28 lb/ft^3) required over 110 days (Anthony, 1982). The bales attempt to reach equilibrium with the environment and the rate of adsorption and desorption is influenced by bale density, ambient temperature and humidity, bale covering, surface area, air changes, fiber history, etc. (Anthony, 1997). Anthony (1982) stored low-moisture bales for periods up to one year in jute, burlap, woven polypropylene, strip-laminated woven polypropylene, dimpled polyethylene and polyethylene bagging. Bales covered in the relatively impermeable polyethylene required much more time (over 365 days) to equilibrate with the environment than the other bale coverings (over 120 days).

Anthony and Herber (1991) studied the moisture transfer characteristics of universal density bales in burlap, woven polypropylene with laminated strips of polyethylene to prevent fibrillation, and polyethylene with 0.95 cm (3/8-in.) diameter perforations on 45.7 cm (18-in.) centers to allow air to escape during bag emplacement. The bales were packaged at 3.5% moisture and stored at 21.1°C (70°F) and 80% RH. They reported that the woven polypropylene-covered bales reached equilibrium in less than 161 days whereas the polyethylene-covered bales had not reached equilibrium after 378 days. After 161 days, the polyethylene-covered bales had gained only about 40% as much moisture as the polypropylene-covered bales. Barker and Laird (1993) reported that desorption occurs at about twice the rate of adsorption for small samples of lint. Thus, bales should lose moisture much faster than they gain moisture.

In 2002, U.S. bales were packaged mostly in woven polypropylene (strip-coated or fully coated) (53%), polyethylene (39%), and burlap, (8%) (Thompson, 2003). The cotton industry is seeking a bagging that does not allow foreign matter to enter, but does allow moisture transfer. These two features are not compatible in the same bagging, thus a compromise must be reached in permeability. The traditional strip-coated woven polypropylene bag is strong and allows adequate moisture transfer. The traditional, relatively impermeable polyethylene bag limits contamination from dust and dirt but is weak and does not allow rapid moisture transfer. Merging these two features (strength and permeability) into one bagging can be accomplished by sacrificing some permeability and fully coating the interior (or exterior) of a woven polypropylene bag with a thin layer of polyethylene. However, this must be carefully done so that adequate permeability to moisture can be retained. In addition, bales are normally “stuffed” into the bale bag mechanically through the one open end, and the air in the bag is rapidly displaced by the cotton bale. As a result, a means for the air to exit must be provided. This can be done by cutting slots or holes near the sealed end of the bag or by omitting sections of the coating. Both these alternatives are currently available.

The purpose of this research was to determine the moisture transfer and weight gain of universal density cotton bales packaged in strip-coated and fully coated bags and stored at different humidities. Be sure to have someone proofread your paper. It will not be proofread by ASAE staff.

METHODOLOGY

The types of bagging material used in this study involved both woven polypropylene bags with extrusion-coated strips to prevent fibrillation as well as similar bags that were fully coated on the interior to reduce contamination. Bags from three different manufacturers were used. Twelve bales of cotton were ginned for this study and covered in four different bale covering materials as follows: (1) Woven polypropylene spiral sewn bags with alternating extrusion-coated and uncoated strips, 7.6 cm (3-in.) wide, 4.7 wrap yarns per cm x 3.1 weft yarns per cm bag construction (*SpecCADY*); (2) woven polypropylene spiral sewn bags with alternating extrusion coated and uncoated strips 7.6 cm (3-in.) wide, 1050 denier by 1050 denier, with a 3.9 wrap yarns per cm x 2.8 weft yarns per cm bag construction (*SpecWPP*); (3) fully coated, woven polypropylene spiral sewn bags with coated seams with 20 each 3.8 cm (1½-in.) moon shaped vent holes (*Coatmoon*); and (4) fully coated, woven polypropylene spiral sewn bags with 7.6 cm (3-in.) wide uncoated seams, 3.9 wrap yarns per cm x 2.8 weft yarns per cm bag 4.7 x 3.3 bag construction (*Langston*) (Table 1). Three bales were covered in each of these test materials.

The bales were ginned using a standard gin machinery sequence on May 23, 2002. About 635.6 kg (1400 lbs) of seed cotton was ginned to produce each 227 kg (500 lb) bale for each treatment. The cotton was processed through a dryer, cylinder cleaner, stick machine, dryer, cylinder cleaner, extractor feeder/gin stand, and one saw-type lint cleaner in the full-scale gin at the Stoneville Ginning Lab.

Samples were taken as the cotton came up the lint flue to the battery condenser for High Volume Instrument (HVI) evaluation (5 each), moisture determination by the oven method (ASTM, 1971) (10 each), and Advanced Fiber Information System (AFIS) (5 each) analyses. After moisture was added, 10 samples were taken for lint moisture evaluation. The bales were pressed to a platen separation of about 48.3 cm (19-in.) and restrained with 9-gauge, 226.1 cm (89-in.) long wire ties. Each bale was placed in a six-mil thick polyethylene bag (Figure 1) until the ginning phase was completed, then the bales were placed in the appropriate bagging for storage at ambient conditions for the required storage period.

The bales were stored in Building 27 at 70% relative humidity (RH) and 21.1 °C (70 °F) for 140 days. The humidity was reduced to about 50% on October 12, 2002, according to the test plan but the dehumidifiers would not immediately bring the humidity down because the bales were also giving up moisture. The RH was generally lower for the next 88 days of storage.

The thickness of each bale was measured with calipers between ties 2 and 3 when the bales were weighed. These measurements were made at the thick part of the bale commonly known as the “hump” using specially constructed calipers that included a flat plate on each side of the caliper blades (Figure 2). Although a wide flat plate was added to the calipers and measurements were made by the same technician, the precision of the thickness measurement was about 0.25 cm (0.10-in.) due to the compressibility of the cotton. The 12 bales were weighed and measured 2 times per week for about 229 days while they were exposed to the temperature and humidity in the room. As the bales were weighed, they were rotated to a different location in the conditioning room because of possible climatic isoclines in the storage room.

The bales were taken out of storage after 229 days of storage on January 9, 2003 and laid on the floor in the full-scale gin. Ten intermediate locations (layers) were identified and marked before the bale ties were removed so that samples could be taken at specific locations within the bale (Figure 3). Layers were identified beginning about 7.6 cm (3-in.) from a rounded side of the bale and proceeding across the bale in about 6.4 cm (2½-in.) intervals. Sub-samples were taken at each layer for oven-based moisture content (10), Advanced Fiber Information System (AFIS) (10), and High Volume Instrument (HVI) classification (10). The classification analysis was done at the Agricultural Marketing Service, Dumas, AR, and the moisture and AFIS analyses were

done at the Stoneville Ginning Lab. The before and after storage samples for classification were processed at the same time in order to remove instrument bias. The AFIS samples were processed in a similar fashion.

RESULTS AND DISCUSSION

Moisture and Weight

Initial moisture contents ranged from 3.46% to 3.75% for all bales (Table 2). After 140 days of storage at 70% RH, estimated moisture ranged from 4.77% for one of the *Coatmoon* covered bales to 6.94% for one of the *SpecWPP* bales. Final bale moisture after storage at 70% RH for 140 days and then at 50% RH for 88 days ranged from 4.92% for one of the *Coatmoon* bales to 5.94% for one of the *SpecCADY* bales. After 140 days of storage at 70% RH, the average weight gain was 3.3, 3.2, 2.1 and 1.3%, respectively, for the *SpecWPP*, *SpecCADY*, *Langston* and *Coatmoon* bagging (Table 3) or 7.5, 7.2, 4.8, and 2.9 kg (16.5, 15.9, 10.5 and 6.5 lbs) of weight. The change in moisture and weight was significant for bagging (Table 4). The mean data for weight change and moisture change are given in Table 5 for the entire storage period. The average weight change for the entire storage period was 2.5, 2.3, 2.1, and 1.5%, respectively, for the *SpecWPP*, *SpecCADY*, *Langston* and *Coatmoon* bagging.

The weight gain data as a function of day of storage is plotted in Figure 4. The weight change for the four types of bagging followed different slopes with the two strip-coated materials being very similar. The fully coated woven polypropylene bagging with the 3.8 cm (1½-in.) moon holes (*Coatmoon*) gained weight much more slowly than the strip-coated materials. The weight gain for the bales in the *Langston* bags was more than the *Coatmoon* bagging but less than the strip-coated material. The predicted moisture as a function of day of storage is in Figure 5. Both the strip-coated materials gained and lost weight much faster than did the fully coated bags. Analyses of variance (SAS, 2001) indicated that weight and moisture gain were significant for Bagging, Storage and their interaction (Table 6). The interaction term was very small compared to the bagging and storage variables and can likely be ignored.

Thickness

The thickness at the hump versus day of storage was significant for Bagging and Storage (Table 6), and means for bale thickness are given in Table 5 across the entire storage period. Means on a periodic basis throughout the storage period are shown in Table 7 for each type bagging. These data suggest that the thickness of the bales increased initially and then remained relatively constant for the remainder of the storage period except for the *Coatmoon* bag that did not change much during storage. Bale

thickness at the hump increased from as low as 0.25 cm (0.1-in.) for the *Coatmoon* bag to 2.0 cm (0.8-in.) for the strip-coated bags after 140 days of storage. The thickness increase for the bales in the *Langston* bag was 1.5 cm (0.6-in.). As the bale moisture dropped when the humidity was lowered, the increase in bale thickness decreased from 2.0 cm to 1.3 cm (0.8 to 0.5-in.) for the bales bagged in strip-coated materials; increased to 0.51 cm (0.2-in.) for the *Coatmoon* material; and remained constant for the *Langston* bagging.

Fiber Quality

The HVI data for the samples taken from the bales before and after storage and their change are in Table 8. Analyses of variance (Table 4) indicated that only the micronaire changed significantly at the 5% level of probability; the change ranged from -0.01 to 0.09 units, which is of no practical importance. However, the micronaire of the bales in the specification bagging changed more than the micronaire in the experimental bagging (0.07 versus 0.02) suggesting that fiber moisture at testing may have affected the measurement.

The AFIS data before bale storage did not differ significantly due to the type of bale covering based on analyses by the General Linear Models procedure (not shown). After storage, 10 samples for AFIS were taken from each of 10 layers inside each bale. Due to time constraints, only 3 of the samples from each layer were analyzed. The 30 samples per bale were randomly combined with the 5 samples before storage and processed with the AFIS. The samples were integrated and analyzed at the same time to overcome potential threshold shifts that were observed in earlier studies. The change in the AFIS data for samples before and after storage was not significant due to type bagging. Means are presented in Table 9 for reference purposes.

SUMMARY AND CONCLUSIONS

This research investigated the weight/moisture change characteristics of universal density cotton bales packaged in woven polypropylene bags with extrusion-coated strips to prevent fibrillation and similar bags that were fully coated on the interior to reduce contamination. Three bales each were ginned, packaged, and placed in four different types of bags—two types of woven polypropylene spiral sewn bags with alternating extrusion-coated and uncoated strips, and two types of fully coated bags. Initial moisture contents averaged 3.6%. The bales were stored for 140 days at 70% relative humidity (RH) and then at 50% RH for 88 additional days. Bales were weighed

twice each week. Samples were taken before and after storage for HVI, AFIS, and moisture.

The thickness of each bale was measured with calipers between ties 2 and 3 when the bales were weighed. These measurements were made at the thick part of the bale commonly known as the “hump” using specially constructed calipers that included a flat plate on each side of the caliper blades. The 12 bales were weighed and measured 2 times per week for about 229 days while they were exposed to the temperature and humidity in the room.

Initial moisture contents averaged 3.6%. After 140 days of storage at 70% RH, the average weight gain was 3.3, 3.2, 2.1 and 1.3%, respectively, for the *SpecWPP*, *SpecCADY*, *Langston* and *Coatmoon* bagging or 7.5, 7.2, 4.8, and 2.9 kg (16.5, 15.9, 10.5 and 6.5 lbs) of weight. The average weight change for the entire storage period was 2.5, 2.3, 2.1, and 1.5%, respectively, for the *SpecWPP*, *SpecCADY*, *Langston* and *Coatmoon* bagging.

The weight change for the four types of bagging followed different slopes with the two strip-coated materials being very similar. The fully coated woven polypropylene bagging with the 3.8 cm (1½-in.) moon holes (*Coatmoon*) gained weight much more slowly than the strip-coated materials. The weight gain for the bales in the *Langston* bags was more than the *Coatmoon* bagging but less than the strip-coated material. Both the strip-coated materials gained and lost weight much faster than did the fully coated bags.

The thickness of the bales increased initially and then remained relatively constant for the remainder of the storage period except for the *Coatmoon* bag that did not change much during storage. Thickness in the bale at the bale hump increased from as low as 0.3 cm (0.1-in.) for the *Coatmoon* bag to 2.1 cm (0.8-in.) for the strip-coated bags after 140 days of storage. The thickness increase for the bales in the *Langston* bag was 1.5 cm (0.6-in.). As the bale moisture dropped when the humidity was lowered, the increase in bale thickness decreased from 2.3 cm to 1.3 cm (0.8 to 0.5-in.) for the bales bagged in strip-coated materials; increased to 0.5 cm (0.2 in.) for the *Coatmoon* material; and remained constant for the *Langston* bagging.

In summary, the bales in fully coated woven polypropylene bagging gained and lost weight much more slowly than those in the strip-coated materials. Fiber properties measured by the HVI and AFIS systems did not change during storage.

DISCLAIMER

Mention of a trade name, proprietary product, or specific machinery does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply approval of the product to the exclusion of others that may be available.

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Table 1. Types of bagging material used in the study.

Type bagging	Types of bale covering material
WPP Striped w/ spec strips [CADY bag]	Specification Woven Polypropylene Spiral Sewn Bags w/ alternating extrusion-coated and uncoated strips, 7.6 cm (3-in.) wide strips, 12 x 8 bag construction. Actually measured 4.5 cm coat by 6.4 cm (1.75-in. coat by 2.5-in.). LPB 45x90. CADY. Bales 1020, 1023, 1029. { <i>SpecCADY</i> }
WPP Striped pattern [AMOCO]	Specification Woven Polypropylene Spiral Sewn Bags w/ alternating extrusion-coated and uncoated strips, 7.6 cm (3-in.) wide strips, 1050 by 1050, 10 x 7 bag construction (AMOCO). Actually measured 6.4 cm coat by 11.4 cm (2.5-in. coat by 4.5-in.). PROPEX 1050. Bales 1022, 1026, and 1030. { <i>SpecWPP</i> }
WPP Fully-coated & Spiral Sewn Seam	Experimental Test Program - Fully-coated Woven Polypropylene, gusseted, Spiral Sewn Bags with coated seams, with 20 each, 3.8 cm (1½-in.) diameter half-moon vent holes (AMOCO). 1050 by 1050, 10 x 7, PROPEX, Bag Length – 241.3 cm (95-in.), bag Width – 252.7 cm (99.5-in.) { <i>COATMOON</i> }
WPP Fully-coated & Spiral Sewn Seam	Experimental Test Program - Fully-coated Woven Polypropylene Spiral Sewn Bags with 7.6 cm (3-in.) wide uncoated seam, 12 x 8.5 bag construction (<i>Langston</i>). Seam Length top to bottom – 350.5 cm (138-in.), Bag Length – 236.2 cm (93-in.), Bag Width – 243.8 cm (96-in.). Uncoated seam about 2.54 cm (1-in.) on one side and 5.1 cm (2-in.) on the other side. 1-1-50. Bales 1021, 1025, 1031. { <i>Langston</i> }

Table 2. Moisture content before storage, after 140 days of storage at 70% relative humidity, and after 88 additional days of storage at 50% relative humidity.

Ginid	Bagging	Bale #	Lint moisture, %, for storage		
			Before ¹	After 140 days ²	After 228 days ³
1	<i>SpecCADY</i>	1020	3.75	6.78	5.87
2	<i>Langston</i>	1021	3.61	5.66	5.48
3	<i>SpecWPP</i>	1022	3.68	6.94	5.79
4	<i>SpecCADY</i>	1023	3.56	6.76	5.87
5	<i>COATMOON</i>	1024	3.59	4.77	4.92
6	<i>Langston</i>	1025	3.69	5.80	5.32
7	<i>SpecWPP</i>	1026	3.64	6.90	5.82
8	<i>COATMOON</i>	1027	3.62	4.97	5.26
9	<i>COATMOON</i>	1028	3.46	4.80	5.01
10	<i>SpecCADY</i>	1029	3.52	6.85	5.94
11	<i>SpecWPP</i>	1030	3.66	7.02	5.93
12	<i>Langston</i>	1031	3.52	5.65	5.62

1) Based on 10 samples. 2) Estimated from bale weight. 3) Based on 100 samples

Table 3. Average weight change and estimated moisture during storage for selected days. Data at 140 days of storage are highlighted in bold print.

Bagging	Day of storage	Weight change		Estimated moisture, %
		Percent	Gain, kg ¹	
<i>COATMOON</i>	0	0.00	0.00	3.56
<i>COATMOON</i>	10	0.22	0.51	3.78
<i>COATMOON</i>	21	0.30	0.68	3.86
<i>COATMOON</i>	31	0.40	0.90	3.95
<i>COATMOON</i>	40	0.50	1.13	4.05
<i>COATMOON</i>	52	0.63	1.43	4.18
<i>COATMOON</i>	62	0.72	1.63	4.28
<i>COATMOON</i>	73	0.82	1.86	4.37
<i>COATMOON</i>	95	0.91	2.06	4.46
<i>COATMOON</i>	102	0.93	2.11	4.48
<i>COATMOON</i>	112	1.08	2.46	4.64
<i>COATMOON</i>	122	1.14	2.58	4.70
<i>COATMOON</i>	132	1.23	2.79	4.79
<i>COATMOON</i>	140	1.29	2.93	4.85
<i>COATMOON</i>	160	1.43	3.24	4.98
<i>COATMOON</i>	173	1.45	3.30	5.01
<i>COATMOON</i>	183	1.47	3.35	5.03

Table 3. Weight change and estimated moisture during storage for selected days. Data at 140 days of storage are highlighted in bold print – continued.

Bagging	Day of storage	Weight change		Estimated moisture, %
		Percent	Gain, kg ¹	
COATMOON	203	1.43	3.25	4.99
COATMOON	214	1.47	3.33	5.02
COATMOON	228	1.45	3.29	5.05
LANGSTON	0	0.00	0.00	3.61
LANGSTON	10	0.46	1.04	4.06
LANGSTON	21	0.58	1.32	4.19
LANGSTON	31	0.74	1.68	4.35
LANGSTON	40	0.91	2.07	4.52
LANGSTON	52	1.12	2.53	4.72
LANGSTON	62	1.24	2.81	4.84
LANGSTON	73	1.39	3.15	4.99
LANGSTON	95	1.54	3.50	5.15
LANGSTON	102	1.57	3.57	5.18
LANGSTON	112	1.78	4.05	5.39
LANGSTON	122	1.85	4.19	5.46
LANGSTON	132	1.99	4.52	5.60
LANGSTON	140	2.10	4.76	5.70
LANGSTON	160	2.23	5.07	5.84
LANGSTON	173	2.20	5.00	5.81
LANGSTON	183	2.20	5.00	5.81
LANGSTON	203	2.06	4.68	5.67
LANGSTON	214	2.09	4.74	5.70
LANGSTON	228	2.01	4.56	5.62
SPECCADY	0	0.00	0.00	3.61
SPECCADY	10	1.26	2.86	4.87
SPECCADY	21	1.64	3.71	5.25
SPECCADY	31	1.94	4.40	5.55
SPECCADY	40	2.20	4.99	5.81
SPECCADY	52	2.40	5.45	6.01
SPECCADY	62	2.45	5.56	6.06
SPECCADY	73	2.53	5.74	6.14
SPECCADY	95	2.70	6.12	6.31
SPECCADY	102	2.71	6.15	6.32
SPECCADY	112	2.75	6.25	6.36
SPECCADY	122	2.85	6.46	6.46
SPECCADY	132	2.97	6.74	6.58
SPECCADY	140	3.19	7.23	6.80

Table 3. Weight change and estimated moisture during storage for selected days. Data at 140 days of storage are highlighted in bold print – continued.				
Bagging	Day of storage	Weight change		Estimated moisture, %
		Percent	Gain, kg ¹	
<i>SPECCADY</i>	160	2.99	6.79	6.60
<i>SPECCADY</i>	173	2.85	6.46	6.46
<i>SPECCADY</i>	183	2.67	6.05	6.28
<i>SPECCADY</i>	203	2.38	5.39	5.99
<i>SPECCADY</i>	214	2.37	5.38	5.98
<i>SPECCADY</i>	228	2.25	5.10	5.86
<i>SPECWPP</i>	0	0.00	0.00	3.66
<i>SPECWPP</i>	10	1.25	2.83	4.91
<i>SPECWPP</i>	21	1.81	4.10	5.47
<i>SPECWPP</i>	31	2.01	4.57	5.67
<i>SPECWPP</i>	40	2.27	5.15	5.93
<i>SPECWPP</i>	52	2.46	5.59	6.12
<i>SPECWPP</i>	62	2.52	5.72	6.18
<i>SPECWPP</i>	73	2.63	5.97	6.29
<i>SPECWPP</i>	95	2.75	6.24	6.41
<i>SPECWPP</i>	102	2.77	6.29	6.43
<i>SPECWPP</i>	112	2.88	6.53	6.54
<i>SPECWPP</i>	122	2.95	6.70	6.61
<i>SPECWPP</i>	132	3.06	6.96	6.72
<i>SPECWPP</i>	140	3.30	7.48	6.96
<i>SPECWPP</i>	160	3.26	7.40	6.92
<i>SPECWPP</i>	173	3.02	6.85	6.68
<i>SPECWPP</i>	183	2.85	6.47	6.51
<i>SPECWPP</i>	203	2.59	5.87	6.25
<i>SPECWPP</i>	214	2.59	5.89	6.25
<i>SPECWPP</i>	228	2.51	5.71	6.16

1) Adjusted to 227 kg (500 lb) Bale

Table 4. Analyses of variance for the change in weight, moisture and HVI factors before and after storage.

Source of variation	DF	Means squares for					
		Weight change, %	Moisture change, %	Length change, x 10 ⁴	Mike change	Strength change	Rd change
Bagging	3	0.56**	0.37**	0.28 ns	0.003 **	1.19 ns	0.14 ns
Error	8	0.02	0.03	0.40	0.00029	1.98	0.11
Mean		2.08	1.96	0.005	0.045	-0.15	-0.28
MSE		0.13	0.16	0.006	0.012	1.41	0.34
CV		6.31	8.41	119.58	38.18	-908.81	1117.88
R-Square		0.92	0.84	0.21	0.79	0.18	-0.32

Source of variation	DF	Means square for				
		Plus b change	Leaf change	% area change, x 10 ⁵	Uniformity change	Mode color change
Bagging	3	0.065 ns	0.0085 ns	0.95 ns	0.14 ns	10.99 ns
Error	8	0.015	0.033	2.10	0.28	13.98
Mean		-0.28	0.031	-0.002	0.201	0.4590
MSE		0.12	0.183	0.0046	0.53	3.74
CV		-43.61	592.11	-229.04	263.14	-827.90
R-Square		0.62	0.09	0.15	0.16	0.28

**indicates significance at the 5%level of probability.

Table 5. Means for moisture, weight gain, and thickness separated by Waller/Duncan.

	Variable				
	Daily moisture, %	Moisture change, %	Weight gain, kg	Weight gain, %	Thickness change, cm
Bagging					
COATMOON	4.43D	1.50C	1.98D	1.48C	0.05D
LANGSTON	5.02C	1.87B	3.22C	2.10B	1.19C
SPECCADY	5.96B	2.28A	5.33B	2.25B	1.50B
SPECWPP	6.12A	2.19A	5.58A	2.49A	1.98A

Table 6. Analyses of variance for weight, moisture and thickness change during storage.

Source of variation	DF	Means squares for		
		Weight gain,	Daily moisture	Bale thickness
Bagging	3	2486.089**	109.371**	18.529**
Storage	59	96.919**	3.876**	0.336**
Bagging*Storage	176	3.197**	0.128**	0.035 ns
Error		0.276	0.009**	0.029
Mean		8.866	5.382	0.464
MSE		0.525	0.099	0.17
CV		5.923	1.844	36.57
R-Square		0.991	0.992	0.856

Table 7. Storage conditions and average change in thickness for each type bagging.

Storage day	Change in thickness, cm, for				Temperature, ° C	Relative humidity, %
	<i>Coatmoon</i>	<i>Specwpp</i>	<i>Speccady</i>	<i>Langston</i>		
0	0.000	0.000	0.000	0.000	27	73
10	-0.328	1.430	1.163	0.899	20	71
21	0.414	2.116	1.641	1.377	21	68
31	0.361	2.329	1.534	1.641	21	70
40	0.097	2.276	1.588	1.323	21	68
52	-0.117	1.905	1.430	0.846	21	68
62	-0.328	2.012	1.481	0.635	21	63
73	-0.434	1.798	1.430	0.635	21	64
95	-0.434	1.852	1.481	0.846	21	66
102	-0.434	1.852	1.481	0.846	21	71
112	0.201	2.487	1.694	1.516	21	72
122	0.147	2.433	1.694	1.481	21	62
140	0.254	2.169	2.065	1.430	20	70
160	0.201	2.329	1.748	1.798	22	55
173	0.297	2.276	1.641	1.958	21	51
183	0.361	2.223	1.748	1.748	21	45
203	0.361	2.223	1.852	1.748	17	52
214	0.465	2.487	1.905	1.748	18	56
228	0.465	2.329	1.367	1.481	17	48

Table 8. High Volume Instrument factors before and after bale storage.

	Gin ID	Bale No.	Mike	Strength, g/tex	Rd	Plus b	Leaf	% Area	Length, cm.	Uniformity	Mode color
Before	1	1020	4.93	28.37	77.00	9.52	3.00	0.020	2.870	82.33	21
After			5.02	29.37	77.19	9.38	3.03	0.025	2.860	83.23	21
Change			0.09	1.00	0.19	-0.14	0.03	0.005	-0.010	0.90	0
Before	2	1021	4.98	28.43	78.00	9.76	3.00	0.030	2.832	82.50	21
After			5.01	29.40	77.33	9.25	3.06	0.025	2.852	83.13	21
Change			0.03	0.97	-0.67	-0.51	0.06	-0.005	0.020	0.63	0
Before	3	1022	4.90	28.40	77.60	9.60	3.00	0.023	2.819	82.50	21
After			4.99	28.24	77.09	9.31	3.01	0.024	2.830	82.99	21
Change			0.09	-0.16	-0.51	-0.29	0.01	0.001	0.011	0.49	0
Before	4	1023	4.85	30.95	75.60	9.38	3.00	0.035	2.819	82.50	31
After			4.93	28.71	75.78	9.39	3.31	0.030	2.830	82.90	31
Change			0.08	-2.24	0.18	0.01	0.31	-0.005	0.011	0.40	0
Before	5	1024	4.84	31.08	76.60	9.64	3.00	0.032	2.824	83.00	21
After			4.85	29.01	76.73	9.23	3.04	0.028	2.835	82.92	31
Change			0.01	-2.07	0.13	-0.41	0.04	-0.004	0.011	-0.08	10
Before	6	1025	4.78	27.98	77.20	9.44	3.20	0.024	2.809	83.40	21
After			4.80	28.54	77.02	9.30	3.10	0.027	2.822	82.64	21
Change			0.02	0.56	-0.18	-0.14	-0.10	0.003	0.013	-0.76	0
Before	7	1026	4.68	28.18	76.00	9.76	3.20	0.032	2.804	82.40	22
After			4.75	28.32	75.62	9.54	3.29	0.031	2.804	82.32	32
Change			0.07	0.14	-0.38	-0.22	0.09	-0.001	0.000	-0.08	10
Before	8	1027	4.76	30.60	75.80	9.76	3.00	0.040	2.794	82.40	22
After			4.78	28.64	75.77	9.21	3.22	0.030	2.814	82.62	31
Change			0.02	-1.96	-0.03	-0.55	0.22	-0.010	0.020	0.22	9
Before	9	1028	4.90	27.70	77.00	9.34	3.00	0.024	2.764	82.20	21
After			4.93	28.79	76.62	8.88	3.02	0.025	2.802	82.69	31
Change			0.03	1.09	-0.38	-0.46	0.02	0.001	0.038	0.49	10
Before	10	1029	4.95	28.30	77.00	9.62	3.50	0.030	2.807	83.00	21
After			5.01	28.70	76.27	9.39	3.14	0.025	2.822	82.67	31
Change			0.06	0.40	-0.73	-0.23	-0.36	-0.005	0.015	-0.33	10
Before	11	1030	5.00	27.30	78.00	9.50	3.00	0.023	2.807	82.25	21
After			5.06	28.69	77.24	9.24	3.06	0.022	2.847	82.98	21
Change			0.06	1.39	-0.76	-0.26	0.06	-0.001	0.040	0.73	0
Before	12	1031	5.05	30.30	78.00	9.30	3.00	0.025	2.858	83.50	21
After			5.04	29.32	77.72	9.11	2.98	0.022	2.850	83.31	21
Change			-0.01	-0.98	-0.28	-0.19	-0.02	-0.003	-0.008	-0.19	0

Table 9 Advanced Fiber Information System data before and after storage (see Appendix A for acronyms).

Gin I.D.	Bag	L(w), cm	L(w) (cv)	UQL (w) cm	SFC (w), %	L(n), cm	L(n) (cv)	SFC (n), %	L 5%, cm	L 2.5% cm	Fine	IFC	Mat ratio	Nep size	Nep /gm	SCN size	SCN /gm	Total	Mean	Dust /gm	Trash /gm	VFM
Before																						
1	1	2.50	32.00	3.00	7.80	2.03	48.00	24.46	3.36	3.56	187.60	2.78	0.89	711.00	227.80	1216.00	12.60	333.20	362.80	274.20	59.20	1.33
2	4	2.51	31.92	3.01	7.78	2.03	48.08	24.44	3.37	3.56	188.80	2.76	0.90	717.00	227.20	1265.80	12.00	341.80	357.80	279.60	61.80	1.35
3	2	2.47	32.44	2.98	8.28	1.99	49.02	25.70	3.34	3.53	186.60	2.98	0.89	721.40	223.80	1295.80	12.20	369.20	350.00	306.60	62.80	1.24
4	1	2.46	32.40	2.97	8.26	1.99	49.26	25.76	3.33	3.51	186.40	2.96	0.89	701.20	222.40	1170.20	10.80	446.60	328.60	372.20	74.20	1.20
5	3	2.47	32.08	2.97	8.10	2.00	48.34	25.06	3.32	3.52	186.60	3.02	0.89	716.80	240.60	1185.60	13.80	429.60	329.60	363.80	66.00	1.28
6	4	2.45	33.06	2.97	8.82	1.96	50.40	27.16	3.32	3.50	183.40	3.20	0.88	713.00	250.80	1382.40	11.20	482.80	327.20	409.60	73.00	1.41
7	2	2.40	34.20	2.93	10.00	1.88	52.52	29.82	3.29	3.49	181.60	3.50	0.87	724.60	266.20	1218.40	16.00	724.40	306.60	628.60	95.60	1.94
8	3	2.40	33.30	2.93	9.58	1.91	50.95	28.40	3.27	3.46	183.50	3.35	0.87	725.50	272.00	1297.75	14.25	660.75	305.00	575.00	85.75	1.62
9	3	2.40	32.56	2.90	8.84	1.93	49.42	26.70	3.25	3.45	186.80	3.20	0.89	704.00	238.00	1348.40	10.00	381.40	314.40	327.80	53.40	1.05
10	1	2.42	32.94	2.94	8.96	1.94	50.28	27.26	3.29	3.48	185.00	3.08	0.88	710.40	244.40	1223.80	11.20	497.00	317.40	426.20	70.80	1.36
11	2	2.47	31.54	2.99	8.14	2.01	48.50	25.34	3.33	3.51	187.20	2.96	0.89	704.00	212.60	1355.20	8.60	373.20	305.80	325.40	47.80	1.03
12	4	2.48	31.80	2.98	7.96	2.02	48.14	24.78	3.34	3.53	187.80	2.88	0.89	706.80	234.20	1338.40	9.80	421.60	304.80	366.40	55.00	1.12
After																						
1	1	2.50	32.16	3.02	8.18	2.02	48.92	25.48	3.37	3.56	186.68	3.03	0.89	703.32	202.92	1179.80	10.96	360.24	333.28	302.00	58.04	1.11
2	4	2.51	32.12	3.02	8.12	2.02	48.90	25.40	3.36	3.55	186.88	2.87	0.89	709.96	196.08	1201.68	11.16	344.04	335.72	288.28	55.92	1.09
3	2	2.47	32.62	2.98	8.53	1.98	49.65	26.35	3.33	3.53	185.44	3.22	0.88	714.36	208.68	1242.32	12.52	431.96	321.72	367.76	64.24	1.28
4	1	2.45	32.82	2.97	8.83	1.96	50.30	27.14	3.32	3.52	184.64	3.31	0.88	711.24	220.44	1216.84	12.24	492.88	322.12	419.32	73.60	1.43
5	3	2.46	32.76	2.98	8.58	1.98	49.76	26.46	3.33	3.53	184.60	3.21	0.88	715.68	216.32	1212.04	12.92	508.76	308.88	440.60	68.08	1.38
6	4	2.42	33.77	2.96	9.41	1.92	51.56	28.48	3.31	3.51	182.48	3.44	0.87	717.64	240.16	1250.36	13.04	514.16	306.64	446.80	67.28	1.32
7	2	2.40	34.02	2.93	9.87	1.89	52.14	29.43	3.29	3.48	181.36	3.64	0.87	713.32	265.00	1188.16	13.52	652.84	300.76	570.44	82.36	1.62
8	3	2.42	33.48	2.94	9.35	1.92	51.08	28.18	3.30	3.50	182.42	3.51	0.87	714.67	241.83	1205.00	12.25	620.33	304.83	540.63	79.75	1.56
9	3	2.40	33.26	2.91	9.26	1.91	50.64	27.86	3.27	3.46	183.76	3.21	0.88	716.80	231.64	1221.68	14.36	458.84	312.36	392.72	66.16	1.26
10	1	2.43	33.24	2.95	9.24	1.93	50.94	28.05	3.30	3.50	184.96	3.24	0.88	718.88	214.76	1264.96	12.76	515.12	301.72	447.72	67.36	1.31
11	2	2.48	32.09	2.99	8.17	2.00	48.84	25.48	3.34	3.53	186.56	3.09	0.89	700.20	199.08	1166.12	10.88	421.72	297.48	370.04	51.52	1.07
12	4	2.49	32.18	3.00	8.22	2.00	49.13	25.70	3.35	3.54	186.40	3.06	0.89	706.20	199.40	1228.60	11.96	442.44	303.76	384.12	58.40	1.15



Figure 1. Bales were stored initially in doubled polyethylene bags and later placed in the appropriate bagging for storage in Building 27.

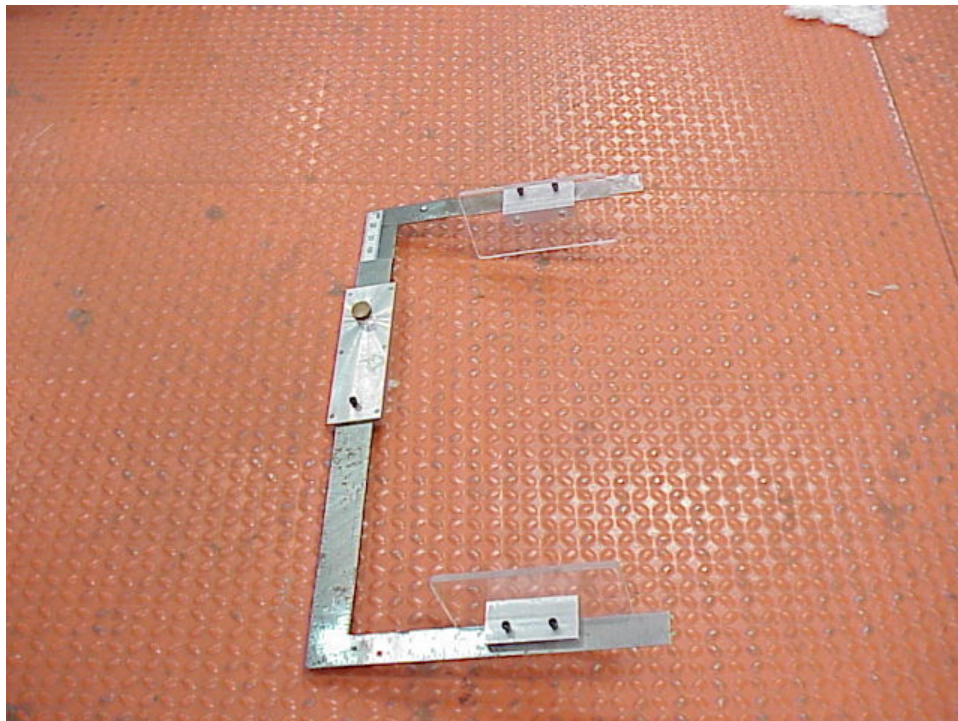


Figure 2. Specially constructed calipers used to measure the thickness at the “hump”.



Figure 3. Bales were divided into 10 layers for sampling purposes.

Error! Not a valid link.Figure 4. Weight gain, kg, as a function of day of storage. The humidity was changed from 70% to 50% after day 140.

Error! Not a valid link. Figure 5. Predicated daily moisture while in storage. The humidity was changed from 70% to 50% after day 140.

Appendix or Nomenclature

NEP SIZE [μ M]	The mean size of all neps (both fiber and seed coat neps) in the sample.
NEPS PER GRAM	The total nep count normalized per gram. This includes both fiber and seed coat neps.
L(W) [CM]	The average length of all the fibers in the sample computed on a weight basis.
L(W) CV [%]	The percentage of the coefficient of variation of the length by weight.
UQL(W) [CM]	Upper quartile length by weight. This is the length which is exceeded by 25% of the fibers by weight.
SFC(W) [%]	The short fiber content of the sample (calculated by weight).
L(N) [CM]	The average length of all the fibers in the sample computed on a number basis.
L(N) CV [%]	The percentage of the coefficient of variation of the length by number.
SFC(N) [%]	The short fiber content of the sample (actual fibers counted by number).
L5%(N) [CM]	The length, calculated by number, that is exceeded by five percent of the fibers.
L2.5%(N) [CM]	The length, calculated by number, that is exceeded by 2.5 percent of the fibers.
TOTAL TRASH [count/gram]	Total trash consists of trash and dust; this is the total of the trash and dust count per gram of the sample.
TRASH SIZE [μ M]	The mean size of all the trash in the sample.
DUST [COUNT/GRAM]	The particles measured by the trash module that are below the size defined as dust on the trash report type setup screen.
TRASH [COUNT/GRAM]	All foreign matter in cotton that is above the size defined as dust is considered trash. This is the amount of trash per gram of the sample.
VFM [%]	The percentage of visible foreign matter (dust and trash) in the sample.
SCN SIZE [μ M]	The mean size of all seed coat neps in the sample.
SCN PER GRAM	The seed coat nep count normalized per gram.
FINE [MTEx]	Fineness - mean fiber fineness (weight per unit length) in millitex. One Thousand meters of fibers with a mass of 1 milligram equals 1 millitex.
IFC [%]	immature fiber content is the percentage of fibers with less than 0.25 maturity. The lower the ifc%, the more suitable the fiber is for dyeing.
MAT RATIO	Maturity ratio - the ratio of fibers with a 0.5 (or more) circularity ratio divided by the amount of fibers with a 0.25 (or less) circularity. The higher the maturity ratio, the more mature the fibers are and the better the fibers are for dyeing.
MICRONAIRE	Micronaire is a measure of fiber fineness and maturity.
STRENGTH	Strength measurements are reported in terms of grams per tex. A tex unit is equal to the weight in grams of 1,000 meters of fiber.
RD AND PLUSB	The color of cotton is determined by the degree of reflectance (rd) and yellowness (+b). Reflectance indicates how bright or dull a sample is, and yellowness indicates the degree of color pigmentation.
PERCENT AREA	Trash is a measure of the amount of non-lint materials in the cotton, such as leaf and bark from the cotton plant. The surface of the cotton sample is scanned by a video camera and the percentage of the surface area occupied by trash particles is calculated.
LENGTH	Fiber length is the average length of the longer one-half of the fibers (upper half mean length).
UNIFORM	Length uniformity is the ratio between the mean length and the upper half mean length of the fibers and is expressed as a percentage.